SOME EFFECTS OF TEMPERATURE ON THE DEVELOPMENT AND OVIPOSITION OF MICROBRACON HEBETOR (SAY)

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The present paper summarizes some preliminary observations on the life history of *Microbracon hebetor* (Braconidae) as a parasite of the Mediterranean flour moth, *Ephestia kühniella* Zeller, under controlled temperature and humidity conditions. This work was done at the Ohio State University in 1931 and the writer is deeply indebted to Professors Alvah Peterson and William M. Barrows for advisory assistance during the progress of the study.

METHODS

The cages used for rearing *M. hebetor* were 18 x 50 mm. shell vials which were closed with screen caps. A fresh, moist, seedless raisin, mounted on an insect pin, was kept in each container as a possible source of moisture and food as a supplement to the normal feeding from punctures made in the host larvae.

Temperature variations were held within about one degree Centigrade on either side of the desired temperature and relative humidity was maintained near 73.0 per cent by means of saturated solutions of sodium chloride.

Examinations of the insects were made daily at about the same hour and two well developed larvae of *E. kühniella* were supplied as hosts to each female parasite. The females were confined singly in cages and were transferred daily to clean vials by means of a suction tube. Fertile females which were reared at 26° and 28° C. were used in the oviposition studies. Males were excluded during the tests to avoid disturbing the oviposition reactions. The eggs, which are deposited externally on the host larvae, were counted by rotating the vial under a binocular microscope.

RESULTS

Pre-imaginal development. The duration of the developmental stadia with standard errors is shown in Table I and is illustrated by Figure 1. The time required by individual insects varied from 8 days at 32° to 39 days at 16° C. The egg and larval stages combined required less than one-half of the time spent within the cocoon or about thirty per cent of the time required from deposition of the eggs to the emergence of the adults. Determinations were made of the duration of the egg and larval periods in combination since the brevity of the stadia made it difficult to determine the values separately.

Between 20° and 32°, the rate of development appears to have a linear correlation with temperature although the regression line may be slightly curvilinear (Fig. 1). These results are, therefore, not strictly in accordance with those of Payne (1934) who states that the curve is probably exponential. However,

TABLE I

Development of *M. hebetor* at Different Constant Temperatures (Duration of the Developmental Stadia in Days)

Temperature ° C.	Egg and Larval Period	Number Reared	Pupal Period	Number Reared	Total Pre-imaginal Period	Number Reared	Index Rate of Development	Thermal Increment (above 12.7) in Day-Degrees
32	2.40	27	5.72	28	8.12 ± .06	28	12.31	156.72
30	2.62	175	6.21	279	8.83 ± .04	279	11.32	152.76
28	3.03	245	6.86	149	9.89 ± .06	149	10.11	151.32
26	3.48	160	8.07	233	11.55 ± .06	233	8.66	153.62
24	4.11	96	9.76	164	13.87 ± .10	164	7.21	156.73
20	6.86	123	14.35	97	21.21 ± .12	97	4.71	154.83
16	10.73	110	21.98	41	32.71 ± .28	41	3.06	107.94

the present study indicates that the curve may be more definitely exponential below 20° since a marked deviation occurs at 16° and a few specimens were reared at 12° which is below the minimum effective temperature shown by the linear relationship. The rate of development used in Table I and Figure 1 is an index which is equal to 100/time, or the per cent of total development which would take place in one day at the mean rate for the entire period. The regression line (Fig. 1) was calculated by the least squares method.

As is shown in the last column of Table I, the thermal increment necessary for the development of *M. hebetor* approaches a constant value for the temperature range between 20° and 32°. Effective temperatures, as are shown in Table I (last column) are those above 12.7° as indicated by the calculated regression line (Fig. 1) and the value of the thermal constant is 154 day-degrees.

As has been recorded previously, (Whiting 1921 and Schlöttke 1926) the coloration of the adults varied progressively from light to dark as the temperature at which they were reared graded downward.

Oviposition. An indication of the fecundity of *M. hebetor* is afforded by a maximum deposition of 312 eggs by one individual while the mode for 53 individuals which were reared at 26° and 28° C. falls between 100 and 200 eggs.

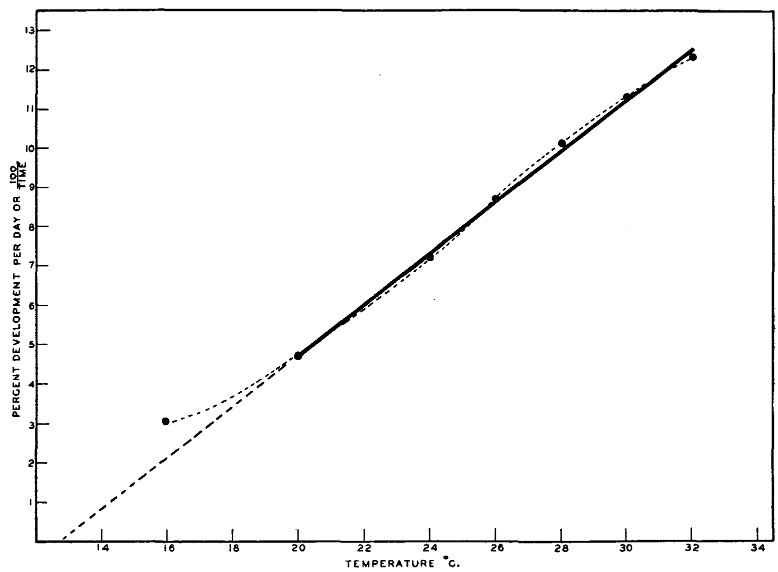

FIG. 1. Graph showing rates of development at different constant temperatures.

The minimum temperature at which eggs were regularly deposited was 14° C. With few exceptions, egg deposition ceased abruptly when laying individuals were transferred to a cabinet which was controlled at 12° C. The maximum temperature at which eggs were regularly obtained was 36° C. Egg-laying was suspended at 38° C. except in the case of exceptional individuals which deposited several eggs under these conditions. The optimum temperature is near 26° C. since the rate of egg-laying is near a maximum at this temperature and the total number of eggs deposited is greater than at higher temperatures where the oviposition period is shorter. The pre-oviposition period is very short since eggs were usually obtained on the first or second day following emergence. A post-oviposition period was not very evident since only a few individuals showed a definite lapse in egg-laying before death occurred. Fertility apparently does not have a marked effect on egg-laying since virgin females exhibit a strong and uniform oviposition behavior. The eggs of virgin females develop but always produce males.

An influence of temperature on the oviposition rate and fecundity of insects has been observed by a number of authors. Hunter and Pierce (1912) observed that the oviposition rate of the cotton boll weevil, *Anthonomus grandis* Boh., was strongly affected by temperature. No data are given but the influence of

TABLE II

Rates of Egg-Laying of *M. hebetor* at Different Constant Temperatures

Temperature -C.	Number of Females	Oviposition Rate (Eggs per Day per Female)	Temperature Coefficients (μ)
38	5	0.00	
36	7	12.59	
28	21	14.70	
26	10	14.57	24,200
24	22	11.10	18,000
22	18	9.03	23,900
20	22	6.85	19,200
18	8	5.47	20,400
16	17	4.29	
14	5	1.80	
12	7	0.00	

temperature is illustrated by a curvilinear regression line. Studies of the effect of temperature on the fecundity of *Trichogramma evanescens* Westwood, show that the oviposition rate of this species is largely a function of temperature. (Schulze 1926). The correlation shown by these data was regarded as curvilinear by Janisch (1930), who fitted the data with an exponential regression curve. The effect of a temperature gradient on the rate of egg-laying of the queen bee is very definitely curvilinear as is shown by Dunham's data (1931). The rate of reproduction of the grain aphis, *Toxoptera graminum* Rondani, is also apparently a curvilinear function of temperature (Wadley (1930) and data of Isely (1932) on the cotton boll weevil suggest a similar relationship.

Data on the rate of egg-laying of *M. hebetor* at various constant temperatures are shown in Table II and are illustrated by

Figure 2. These results also show that the effect of temperature on the oviposition rate is not directly proportional to temperature through an appreciable range. The effect of the temperature gradient appears to define a sigmoid curve between 16° and 28° C. which indicates that the oviposition rate may be better interpreted as an exponential than as a linear function of temperature.

The master reaction theory that the velocities of such processes are controlled by the speed of a single chemical reaction has been quite generally considered by physiologists and temperature characteristics (μ of the Arrhenius equation) have been

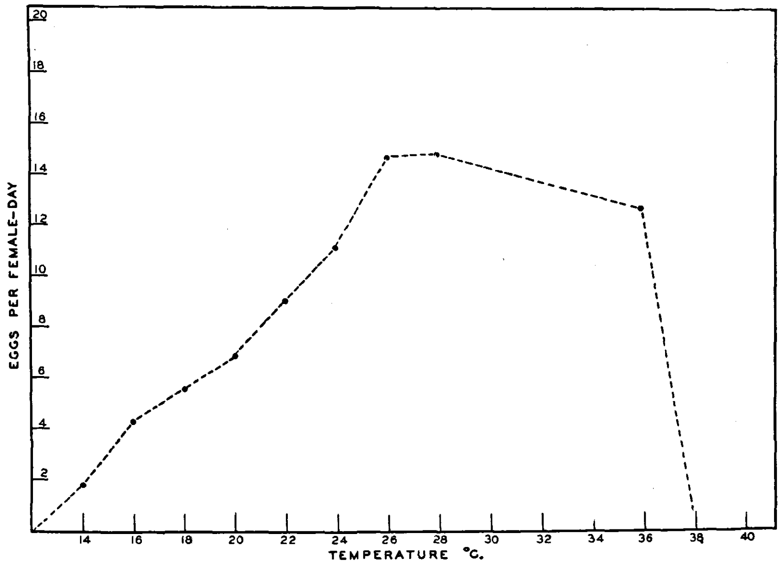

FIG. 2. Graph showing oviposition rates at different constant temperatures.

calculated for a great variety of biological activities. Objections to the use of the Arrhenius formula in biology have been made by Fulmer and Buchanan (1929) and by Belehrádek (1928–30) who advances the theory that the speed of such reactions is dependent upon the viscosity of protoplasm or the "rate of diffusion in viscous media."

Consideration of different regression equations has demonstrated the difficulty of finding the best hypothesis by the method of curve fitting. Variability in the oviposition response as well as the fact that the curve extends only through a narrow temperature range make it evident that a slight difference in agreement in favor of one equation is not significant. However, it is shown in Table II that the oviposition rates are not obviously discordant with the master reaction theory since the value of the temperature characteristic does not vary regularly in any order which would indicate that it is not a constant for the process between 16° and 26° C. The data depart widely from the calculated regression curve at higher temperatures and also at 14° and below the minimum temperature for oviposition since the curve does not reach a zero.

These results indicate that the effect of temperature on the oviposition rate does not permit the simple analysis which is provided by the thermal constant theory for the development of this species since a definite thermal increment does not have a constant effect through any range of temperature. In the case of such relationships, factorial treatment of thermal increments between narrow temperature limits would provide a closer index to the influence of temperature on insect oviposition than would the method of direct temperature summation by day-degrees.

SUMMARY

The approximate duration of the developmental stages of *M. hebetor* has been determined at constant temperatures for the range of 16° to 32° C. The egg and nymphal periods combined require about one-third and the pupal period about two-thirds of the total pre-imaginal period. The data on development conform well to the thermal constant theory between 20° and 32° C. Mean oviposition rates do not indicate a thermal constant but show a sigmoid relationship which shows only a slight difference in the rate of egg-laying between 28° and 32° C. The thermal constant for development has a value of 154 day-degrees and the temperature characteristic for oviposition between 16° and 26° C. has a least squares value of 21,400.

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